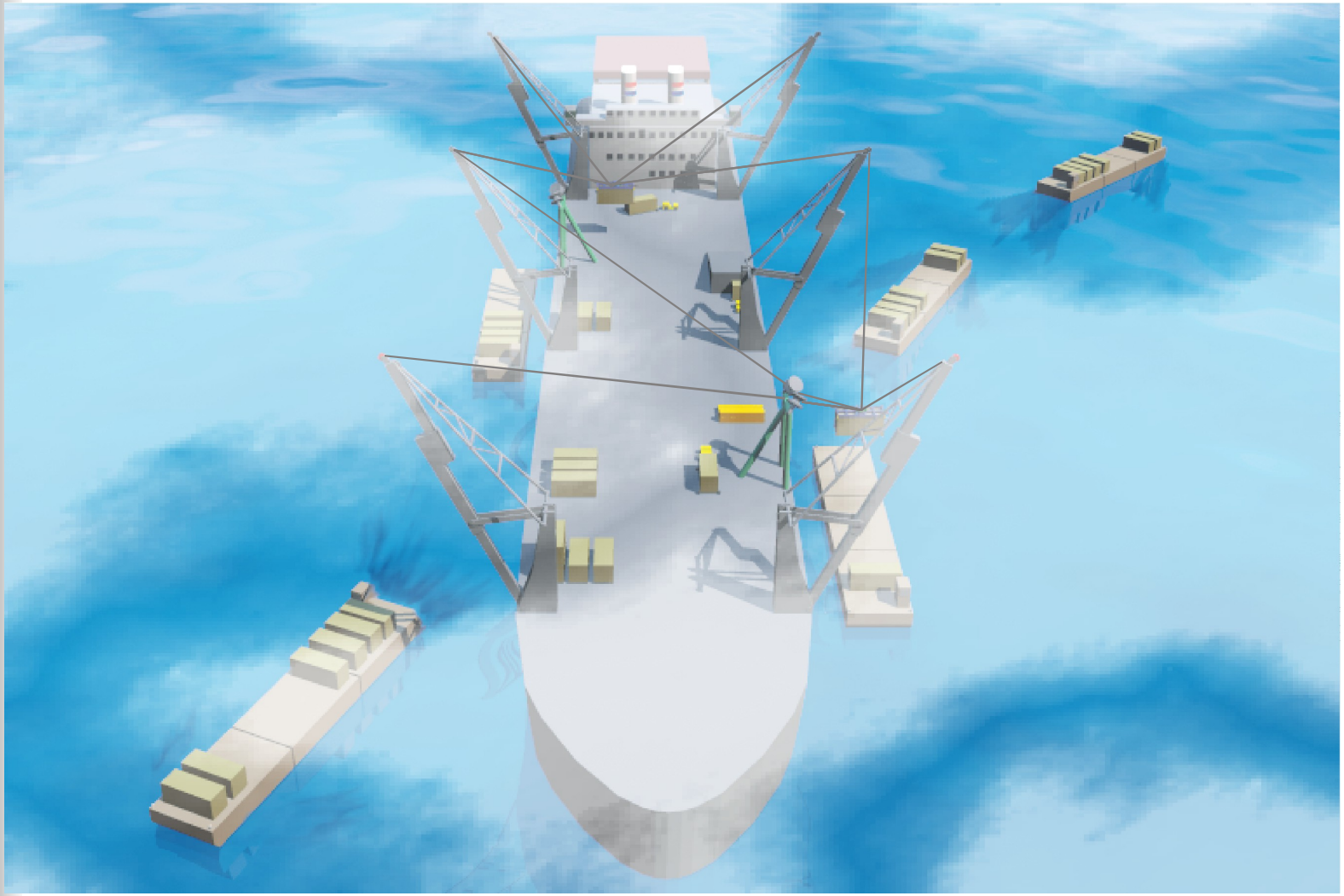
Professor David Cannon
(On sabbatical at NFESC - Navy)

AutoLog Array Crane:

* Stability Concept For Automated Logistics (AutoLog)

Penn State/Seicor/Navy

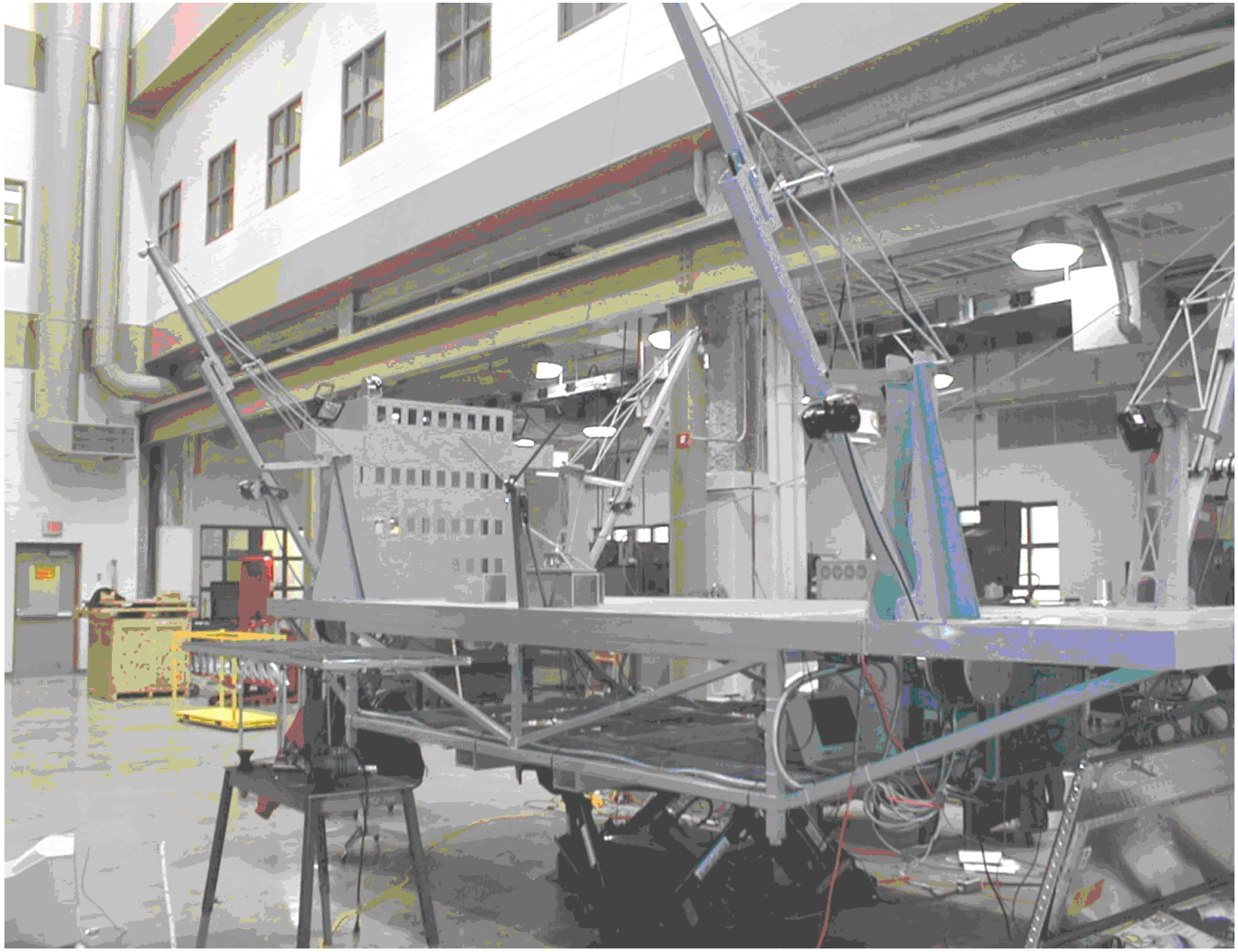
AutoLog Provides Offloading Stability At Sea



Autolog Port-At-Sea: Strategic Offloading

- **Allows Immediate Offloading on Arrival:**
  Globally;
  In Daytime, or at Night;
  In Sea State 3 or Greater;
  At Rapid Cargo Throughput Rates.
- **Turns Container Ships into Ports at Sea.**
- **Provides Low Exposure (No Port Terror).**
- **Creates Offload Options In Higher Seas.**
- **Raises Demand for Existing as well as Future Offloading Ships.**

1/16th Scale PSU AutoLog Model



CONTAINER OFFLOAD
SEA STATE 3+

AutoLog Model at Penn State

- **Completed Scale Up to 1/16th Model from 1/32nd Scale Bench Models**
  - **Kinematics**
  - **Dynamics**
  - **Control**
  - **Mechanism Design**
- **(Facilitated by Having High Bay, Lab and Outdoor Site become Available)**

¼ Scale Ship For Initial AutoLog Demo At Sea

The MV Independence operates from Port Hueneme, CA, where the Navy's NFESC Command is located. (Planned system is drawn in red w/ lighters superimposed.)

Sea Based Logistics

Initial At-Sea D

AutoLog System will be placed aboard the NFESC vessel MV Independence for testing higher sea state conditions.

Sea Based Logistics: AutoLog Land Test Site at

- **Initial hardware under construction.**
- **Will allow Offload operations at sea in high sea states using robotics.**

Sea Based Logistics: High Sea State Technologies (HISEA) Test Site

Amphibious Landing Beach

Site at Port Hueneme to support test and evaluation of high sea state prototypes

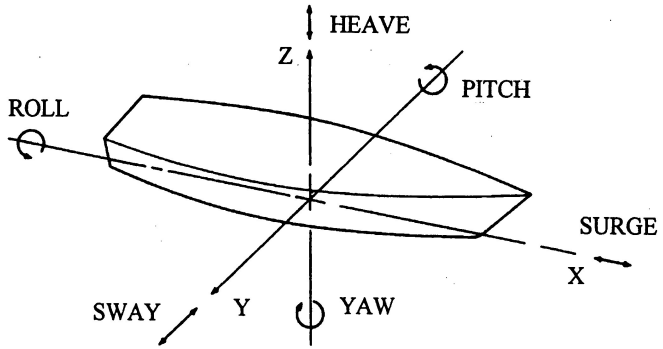
09/10/1 Penn State / Sei 0

One Ideal Ship Type for Full AutoLog Proof of Concept

Skin-To-Skin Transfer Criteria

- **Avoid Problems with 6 DOF Effects**

(i.e. from Roll Pitch Yaw Heave Surge Sway)



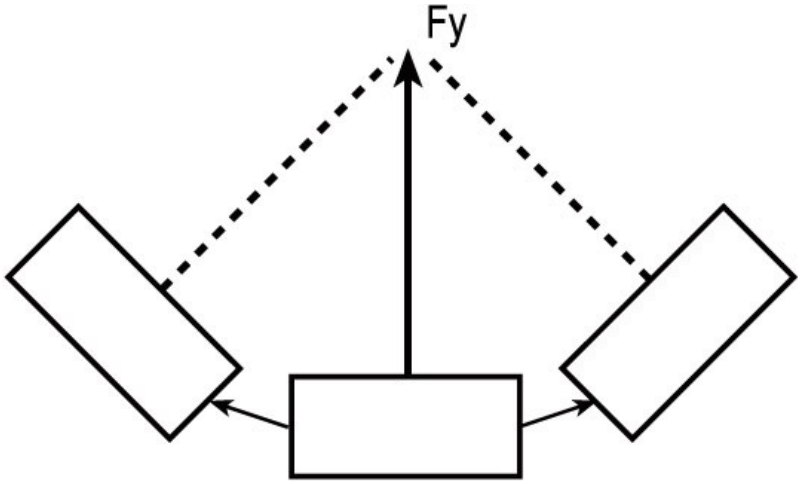
- **Minimize & Distribute Loads/Moments**
- **Maximize Reach & Workspace Area For a Given Boom Torque**
- **Use Technology with Growth Potential**

Array Configuration

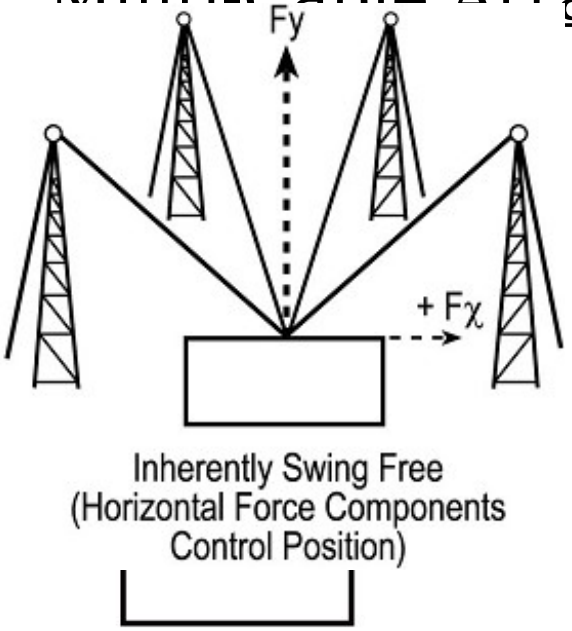
- **AutoLog Array provides horizontal and rotational control authority for the first time.**
- **AutoLog Array Remains Swing-Free Even During Power Loss.**

Array Concept Avoids Problems With 6 DOF Effects (i.e. from Roll Pitch Yaw Heave Surge & Sway)

Single Vertical Cable



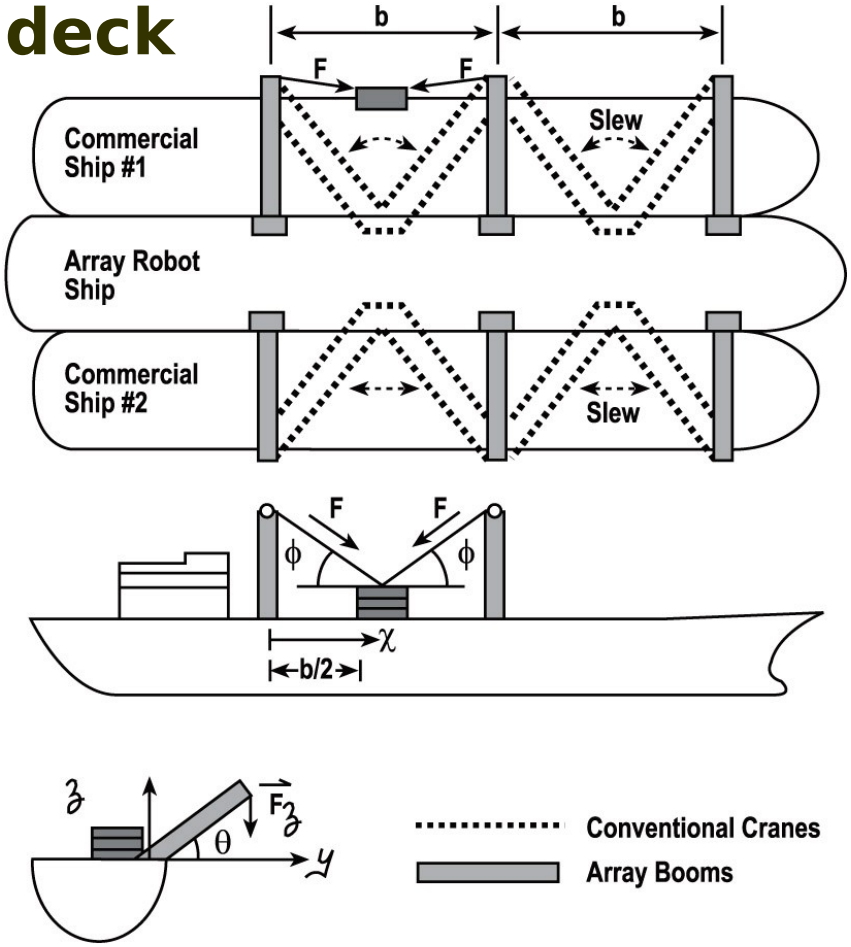
Multi-Cable Array



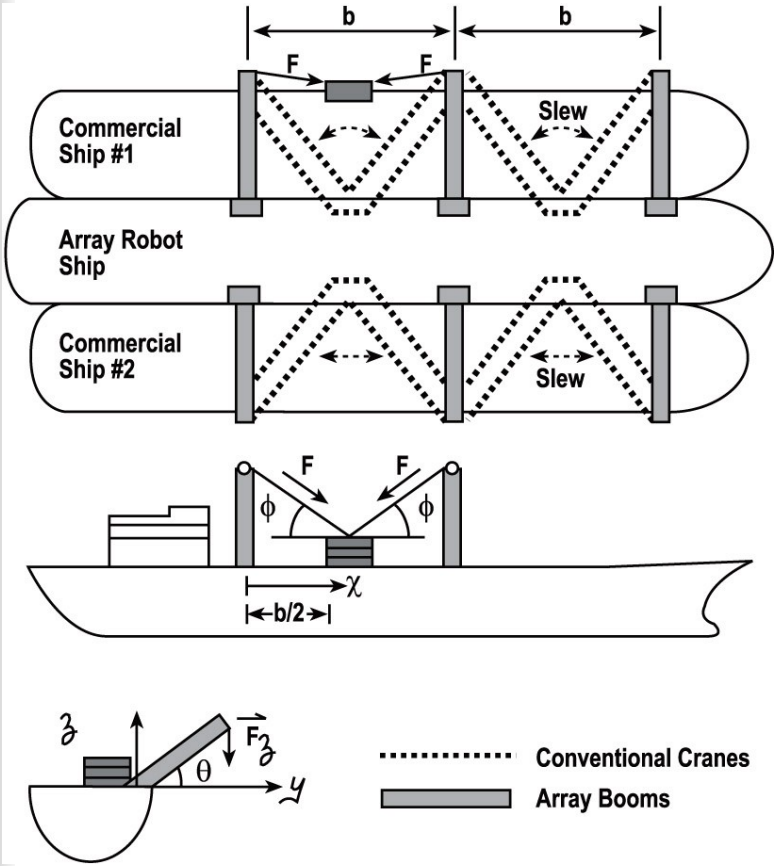
COMPARING
AutoLog - Crane
Scale Pendulation

Sea Basing with AutoLog

- **AutoLog ship-to-ship transfer involves reduced forces and moments to the ship deck**

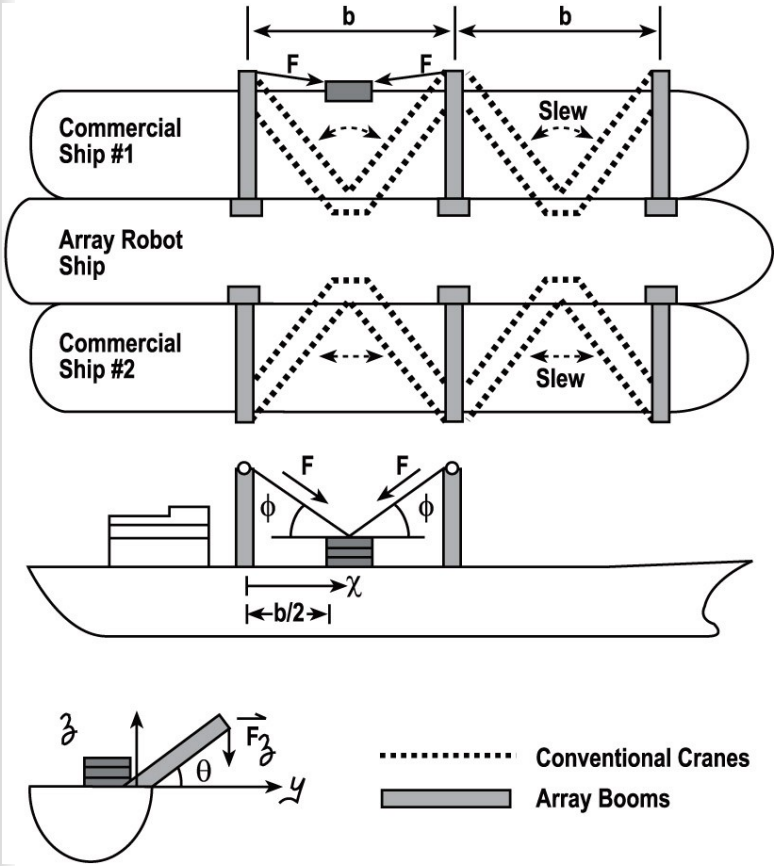


Array Concept Minimizes & Distributes Structural Loads and Moments



- **AutoLog Array has n + 2 fixed booms that distribute load. Only the cables and load move.**
- **AutoLog backstays can be used given fixed booms of an array.**
- **Conventional Cranes, by contrast, must pass all loads and moments through a rotating thruster bearing (dotted lines). No back stays are possible.**

Array Concept Maximizes Reach & Workspace Area For a Given Boom Torque



- **Resultant Conventional Moment Torque =**

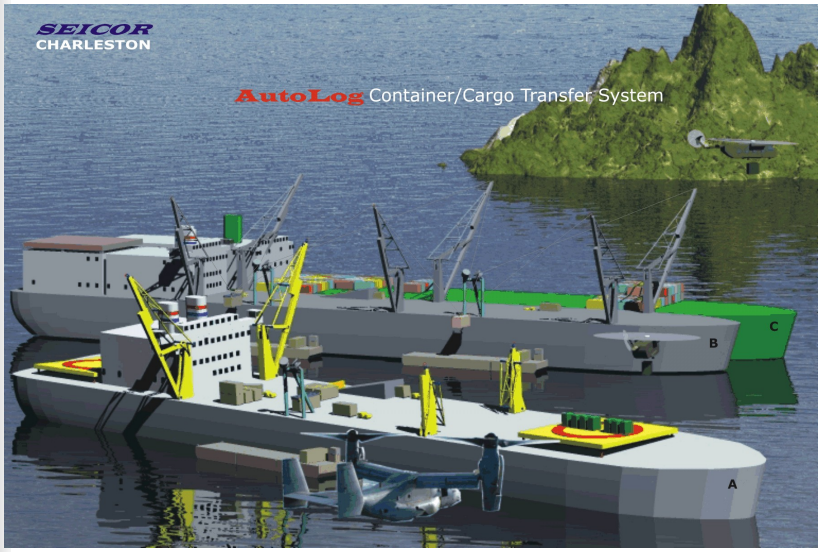
W * (a^2+(b/2)^2)^1/2

- **Resultant Array Moment Torque =**

W * (a^2+h^2)^1/2 * (cos^2Theta + cos^2Phi*Sin^2Theta)^1/2

Conclusion: Array always has less Resultant moment (e.g. 80%)

Array Concept Uses Technology with High Future Growth Potential



- Automated Laser and Vision Assisted Spreader Bar--for capturing containers and landing them smoothly on a moving platform.
- Automated “Put that … there” Human interface--with option to manually drive containers in any direction or rotation as desired.

AutoLog Offloading w/ Other Ships, Lighters a

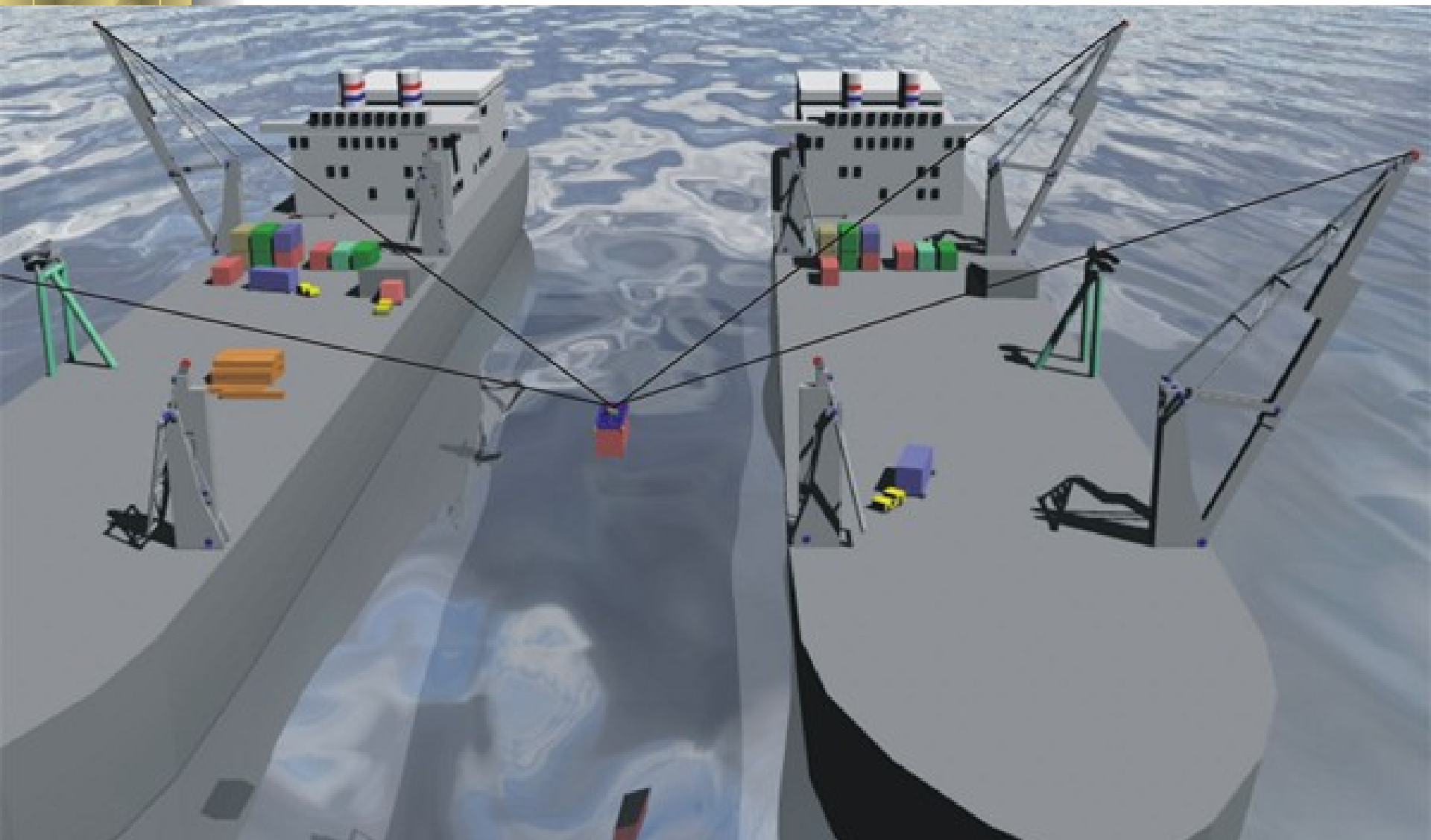
Outdoor Site for: GPS; Natural Light Vision; Laser Guided Landing Tests etc.

- **Power (110V & 220V)**
- **Internet (5 ports)**

Offloading by RC Helicopter (Smaller

- **A live remote control helicopter test was performed for the integrated concept of offloading both vertically by air as well as to lighters at sea.**

Sea Based Logistics
AutoLog Underway



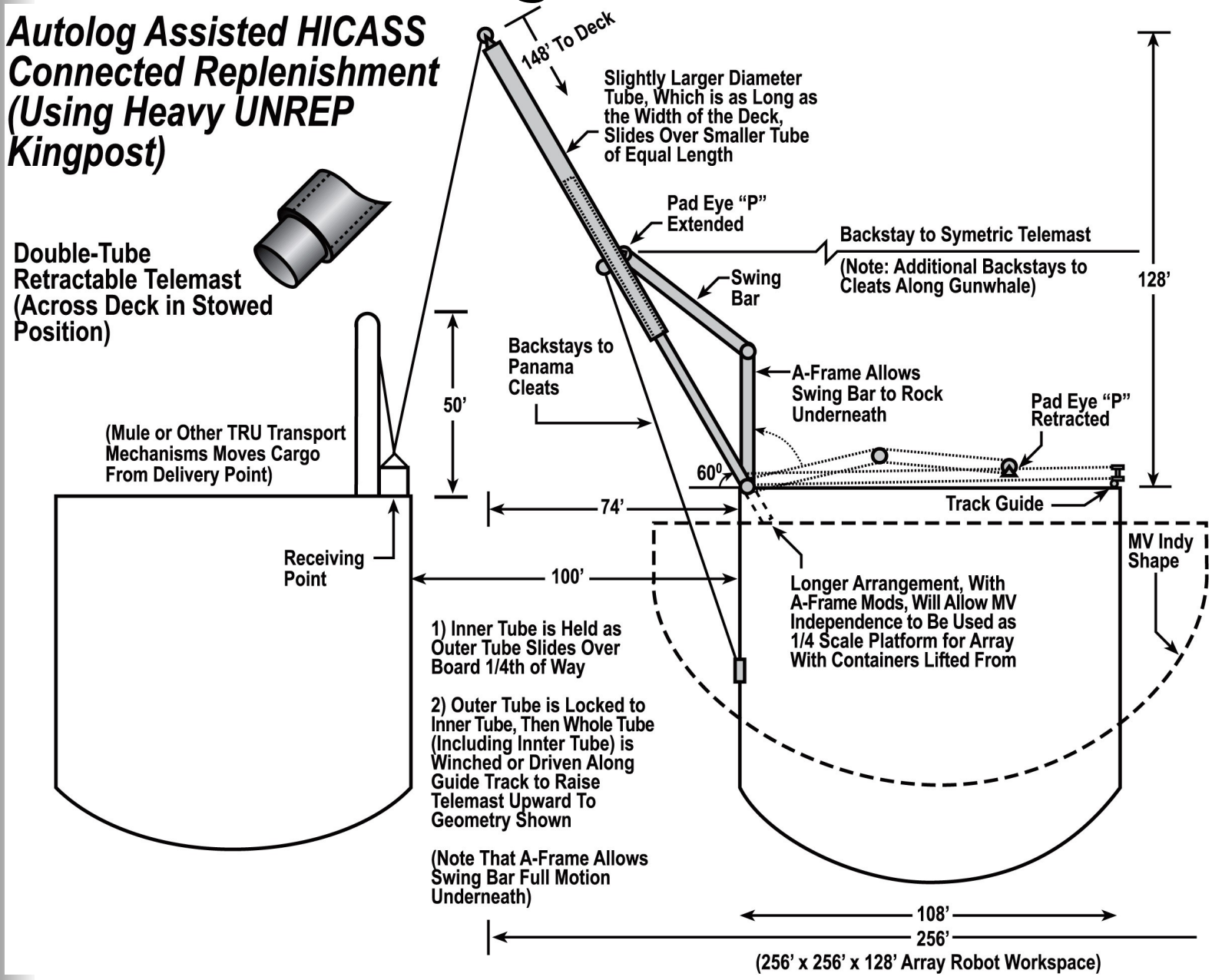
Hybrid UnRep

- **Marvin Miller (NSWC-PHD) Would Like AutoLog with Heavy UnRep**
- **Start With: High Throughput AutoLog Feed To Current UnRep**
- **Keep Current Spacing Between Ships**
- **Keep High Line System with Out- Haul and Back-Haul**

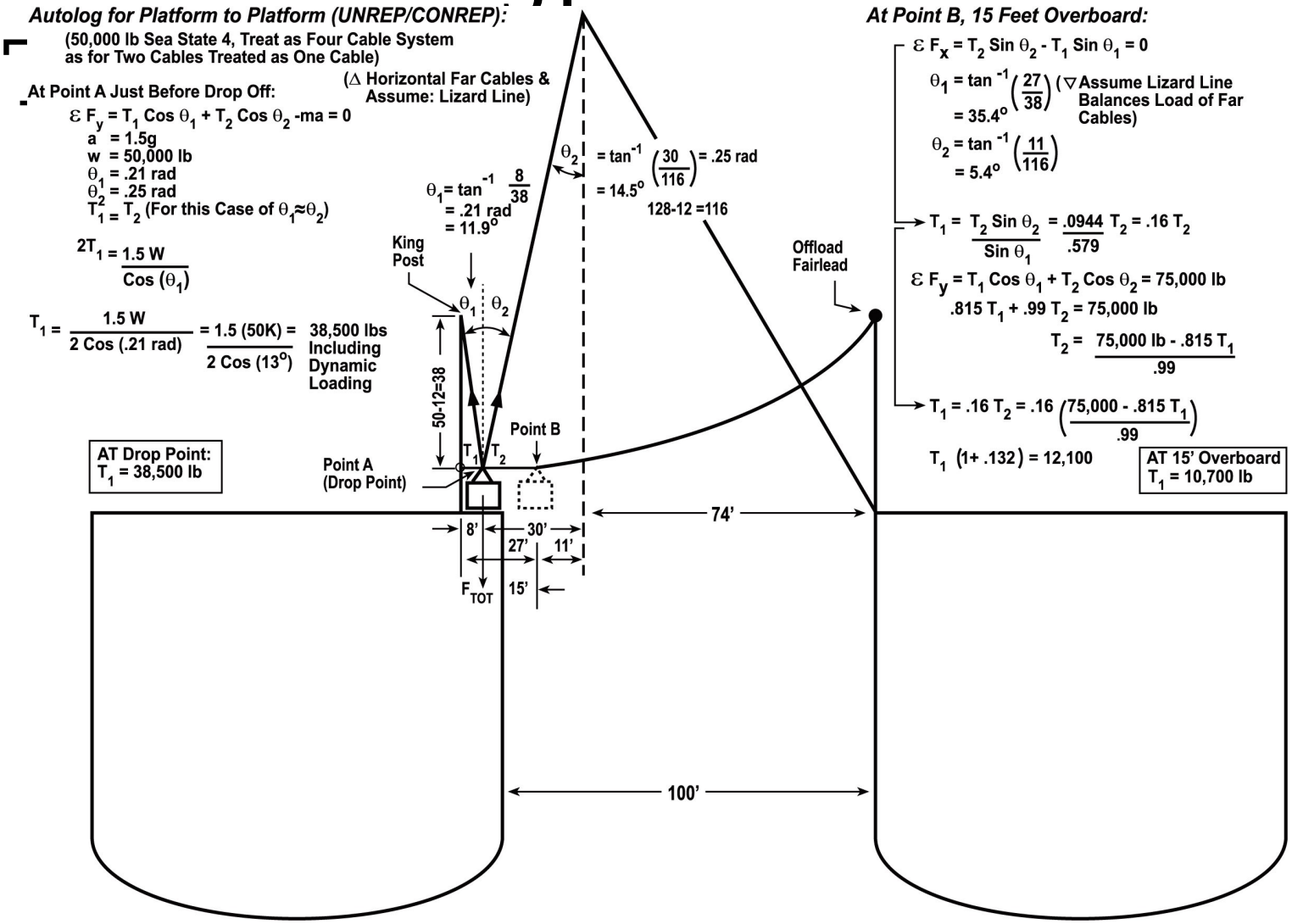
Future Heavy-Lift Assist

- **Later: Multi-Platform Kinematics, Dynamics and Controls for accommodating relative ship motion.**
- **AutoLog Cables carry the extra weight while transferring full containers underway .**
- **Carrier Wave/Differential GPS measures relative platform motions.**

UNREP Using Conventional


Autolog Assisted HICASS Connected Replenishment (Using Heavy UNREP Kingpost)
Double-Tube Retractable Telemast (Across Deck in Stowed Position)
148' To Deck
Slightly Larger Diameter Tube, Which is as Long as the Width of the Deck, Slides Over Smaller Tube of Equal Length
Pad Eye "P" Extended
Backstay to Symetric Telemast
(Note: Additional Backstays to Cleats Along Gunwhale)
Swing Bar
128'
Backstays to Panama Cleats
A-Frame Allows Swing Bar to Rock Underneath
Pad Eye "P" Retracted
50'
(Mule or Other TRU Transport Mechanisms Moves Cargo From Delivery Point)
60°
74'
Track Guide
Receiving Point
100'
MV Indy Shape
Longer Arrangement, With A-Frame Mods, Will Allow MV Independence to Be Used as 1/4 Scale Platform for Array With Containers Lifted From
1) Inner Tube is Held as Outer Tube Slides Over Board 1/4th of Way
2) Outer Tube is Locked to Inner Tube, Then Whole Tube (Including Innter Tube) is Winched or Driven Along Guide Track to Raise Telemast Upward To Geometry Shown
(Note That A-Frame Allows Swing Bar Full Motion Underneath)
108'
256'
(256' x 256' x 128' Array Robot Workspace)

Full Container Transfer < 20 Ton Kingpost Cable


Autolog for Platform to Platform (UNREP/CONREP):
(50,000 lb Sea State 4, Treat as Four Cable System as for Two Cables Treated as One Cable)
(Δ Horizontal Far Cables & Assume: Lizard Line)
At Point A Just Before Drop Off:
ε F_y = T_1 Cos θ_1 + T_2 Cos θ_2 -ma = 0
a = 1.5g
w = 50,000 lb
θ_1 = .21 rad
θ_2 = .25 rad
T_1 = T_2 (For this Case of θ_1≈θ_2)
2T_1 = 1.5 W / Cos (θ_1)
T_1 = 1.5 W / 2 Cos (.21 rad) = 1.5 (50K) / 2 Cos (13°) = 38,500 lbs Including Dynamic Loading
θ_1 = tan^-1 8/38 = .21 rad = 11.9°
θ_2 = tan^-1 (30/116) = .25 rad = 14.5°
128-12 =116
King Post
50-12=38
Point A (Drop Point)
Point B
AT Drop Point: T_1 = 38,500 lb
8'
30'
27'
11'
15'
F_TOT
74'
100'
Offload Fairlead
At Point B, 15 Feet Overboard:
ε F_x = T_2 Sin θ_2 - T_1 Sin θ_1 = 0
θ_1 = tan^-1 (27/38) = 35.4° (▽Assume Lizard Line Balances Load of Far Cables)
θ_2 = tan^-1 (11/116) = 5.4°
T_1 = T_2 Sin θ_2 / Sin θ_1 = .0944 / .579 T_2 = .16 T_2
ε F_y = T_1 Cos θ_1 + T_2 Cos θ_2 = 75,000 lb
.815 T_1 + .99 T_2 = 75,000 lb
T_2 = 75,000 lb - .815 T_1 / .99
T_1 = .16 T_2 = .16 (75,000 - .815 T_1 / .99)
T_1 (1+ .132) = 12,100
AT 15' Overboard T_1 = 10,700 lb

Heavy UnRep Trade-Offs

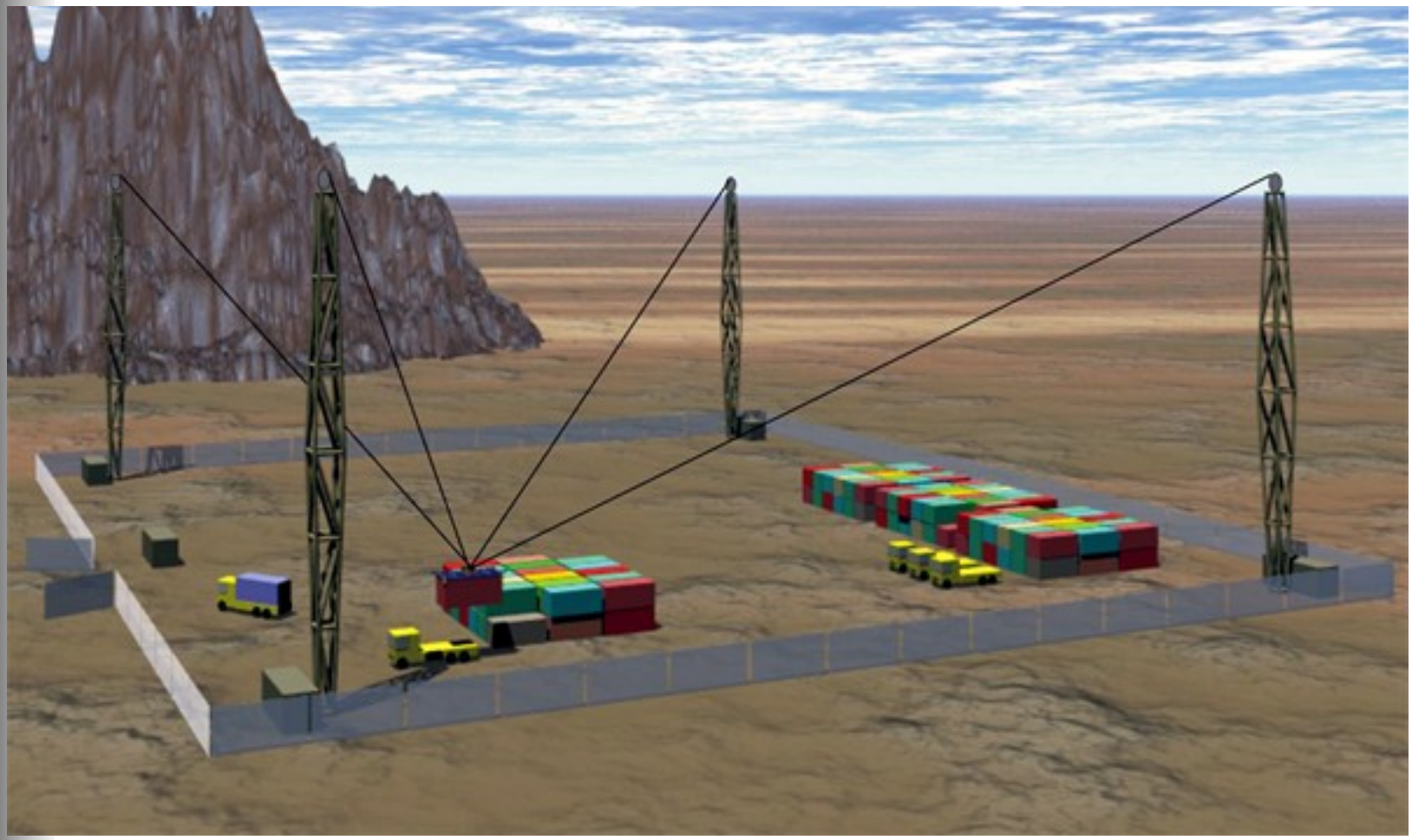
- **Can increase ship spacing if Kingpost (Ram Tensioner) shares higher loads with AutoLog Array.**
- **Can increase throughput if AutoLog feeds High-Line system during light cargo transfers.**

Additional Future Applications

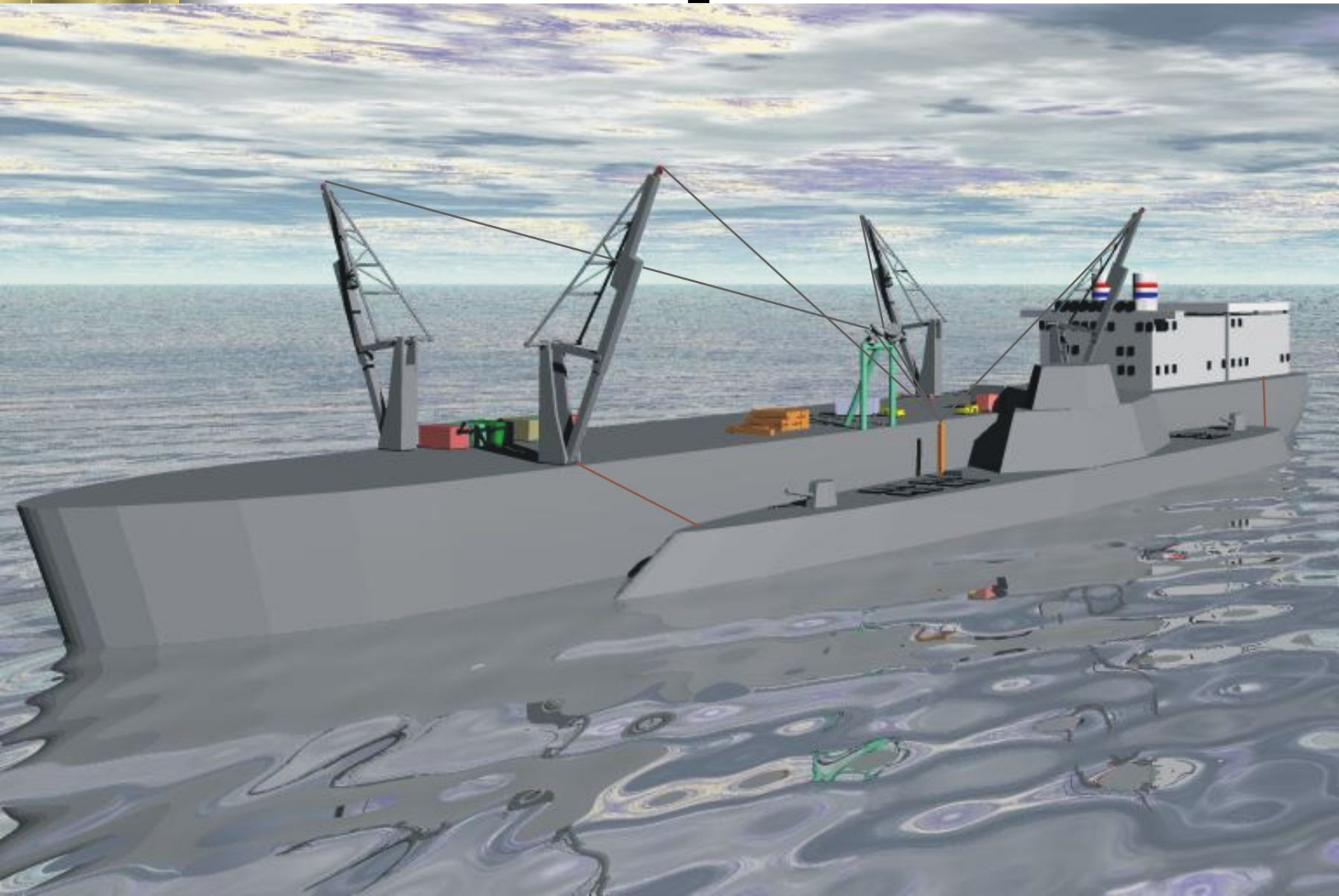
- **New Class of Cable Array Robotic System**
- **Many Opportunities for Stabilization in Crane Related Navy Tasks.**
- **Three Examples and Many More:**

AutoLog Beach Marshalling Yard

AutoLog Field/Depot



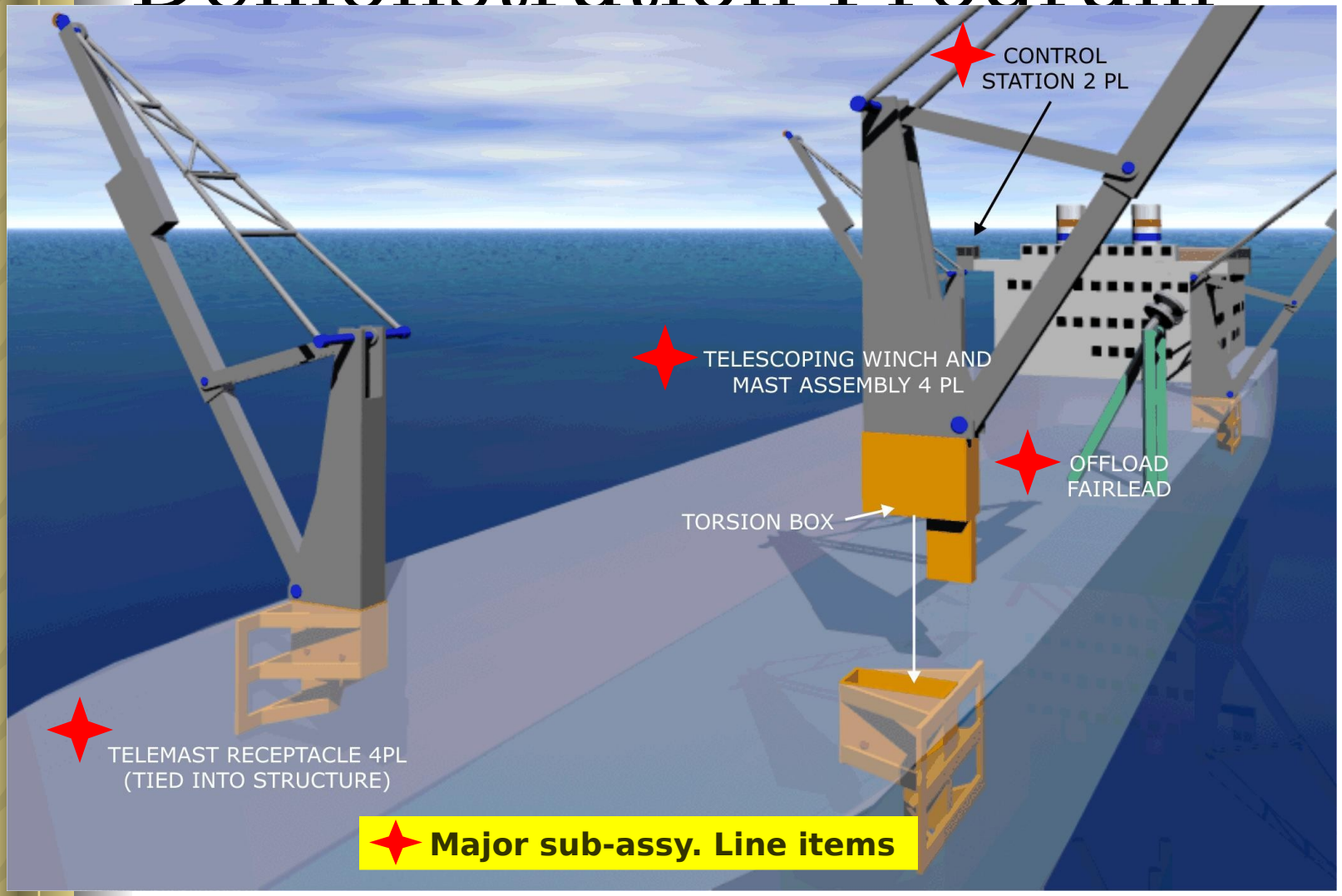
Missile Replenishment



AutoLog Subsystem Details

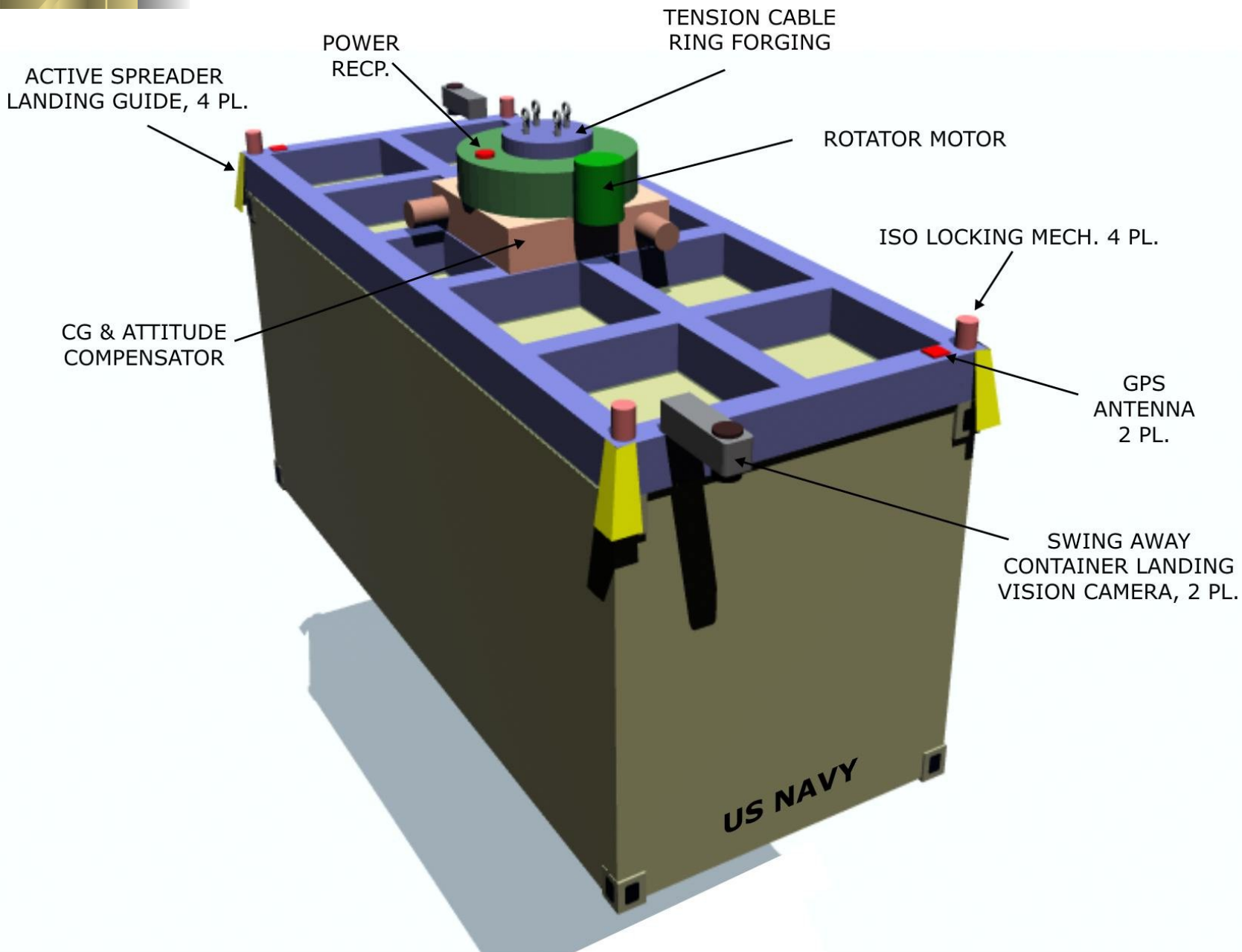
- **Deployable Fixed TeleMasts**
- **Active Spreader Bar**
- **GUI Human Interface to AutoLog**
- **Messenger Spreader for Hull Lifts**
- **Single Wrap Winch Drums**

Proof of Concept Demonstration Program


CONTROL STATION 2 PL
TELESCOPING WINCH AND MAST ASSEMBLY 4 PL
OFFLOAD FAIRLEAD
TORSION BOX
TELEMAST RECEPTACLE 4PL (TIED INTO STRUCTURE)
Major sub-assy. Line items

Retractable Fixed TeleMast

Active Spreader



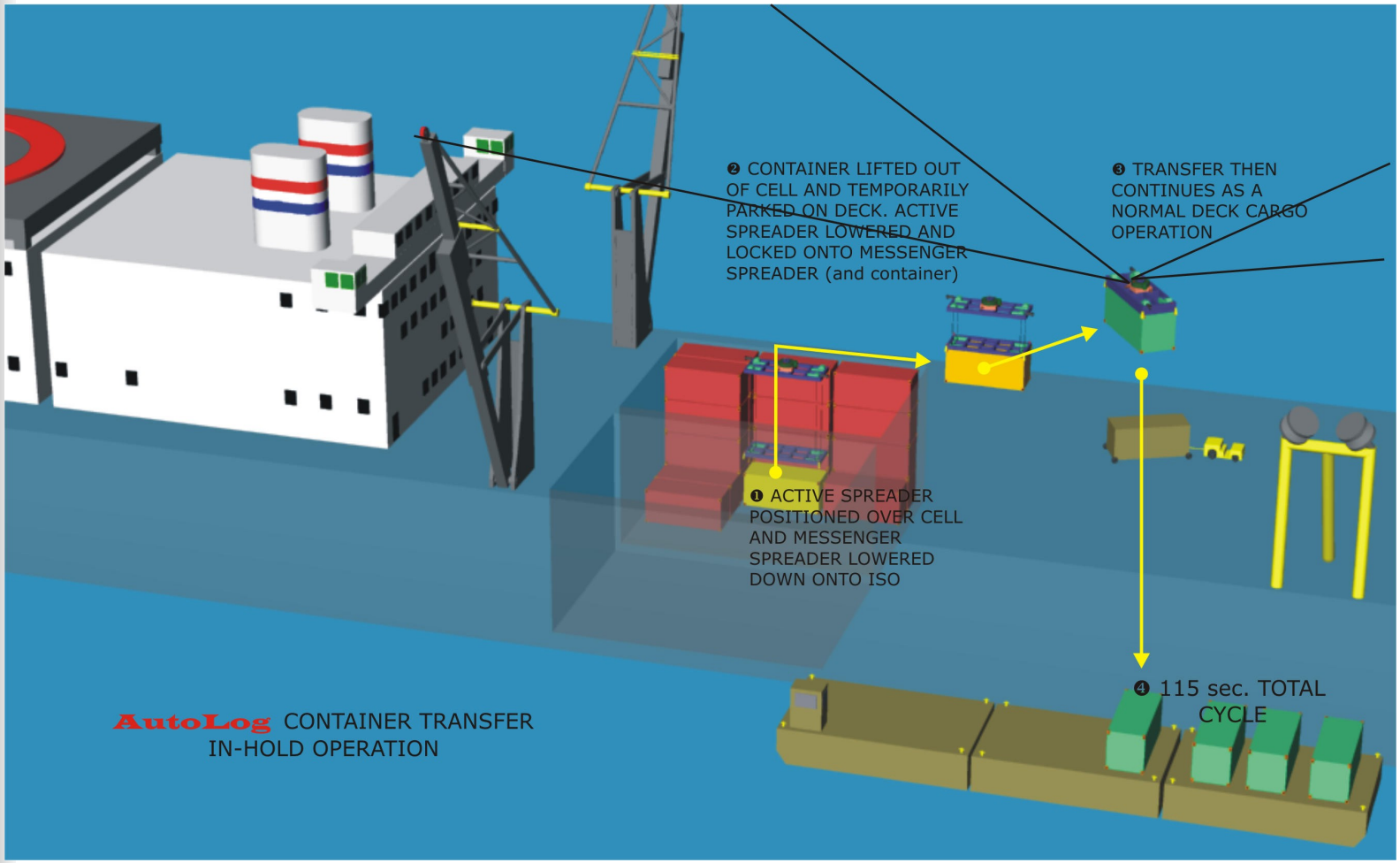
PSU Laser Guided Landing Test

- ¼ Scale Container
- Suspended from Telemasts on Crane Rails
- Viewed From Ship Bridge (2nd Floor Lab Window)

Lasers For Guided Landings

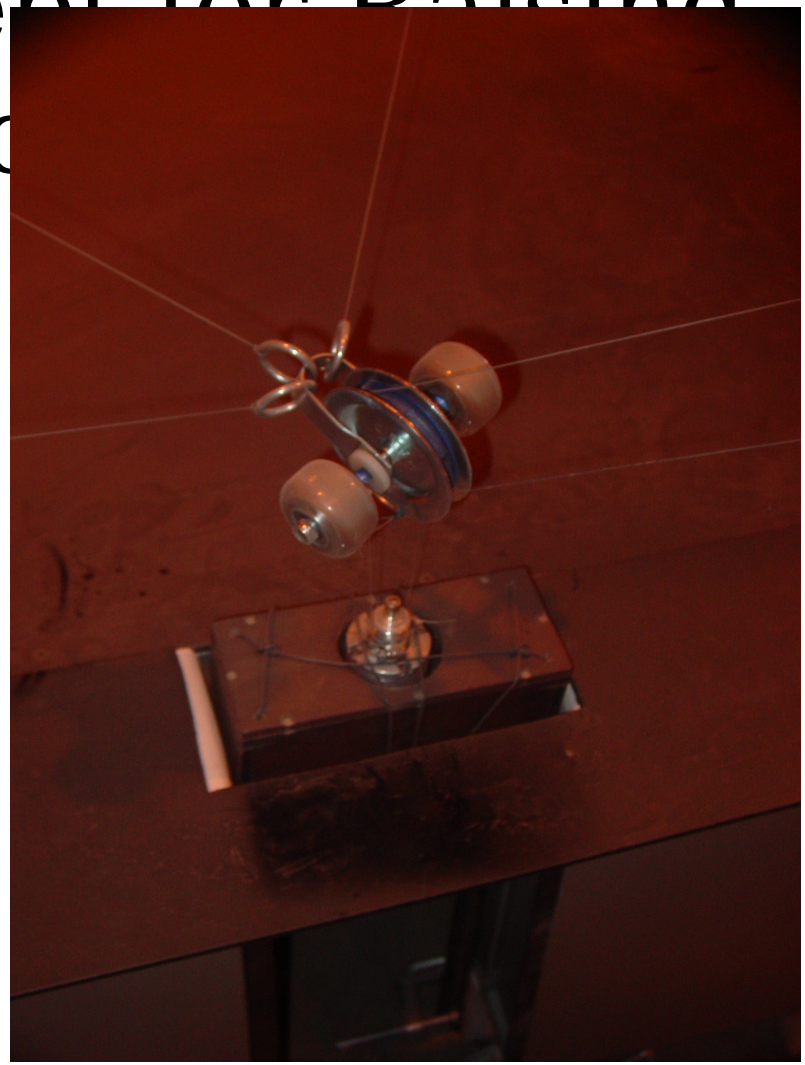
Lands Flat ; Lands Adiacent

Container Retrieval From Hold

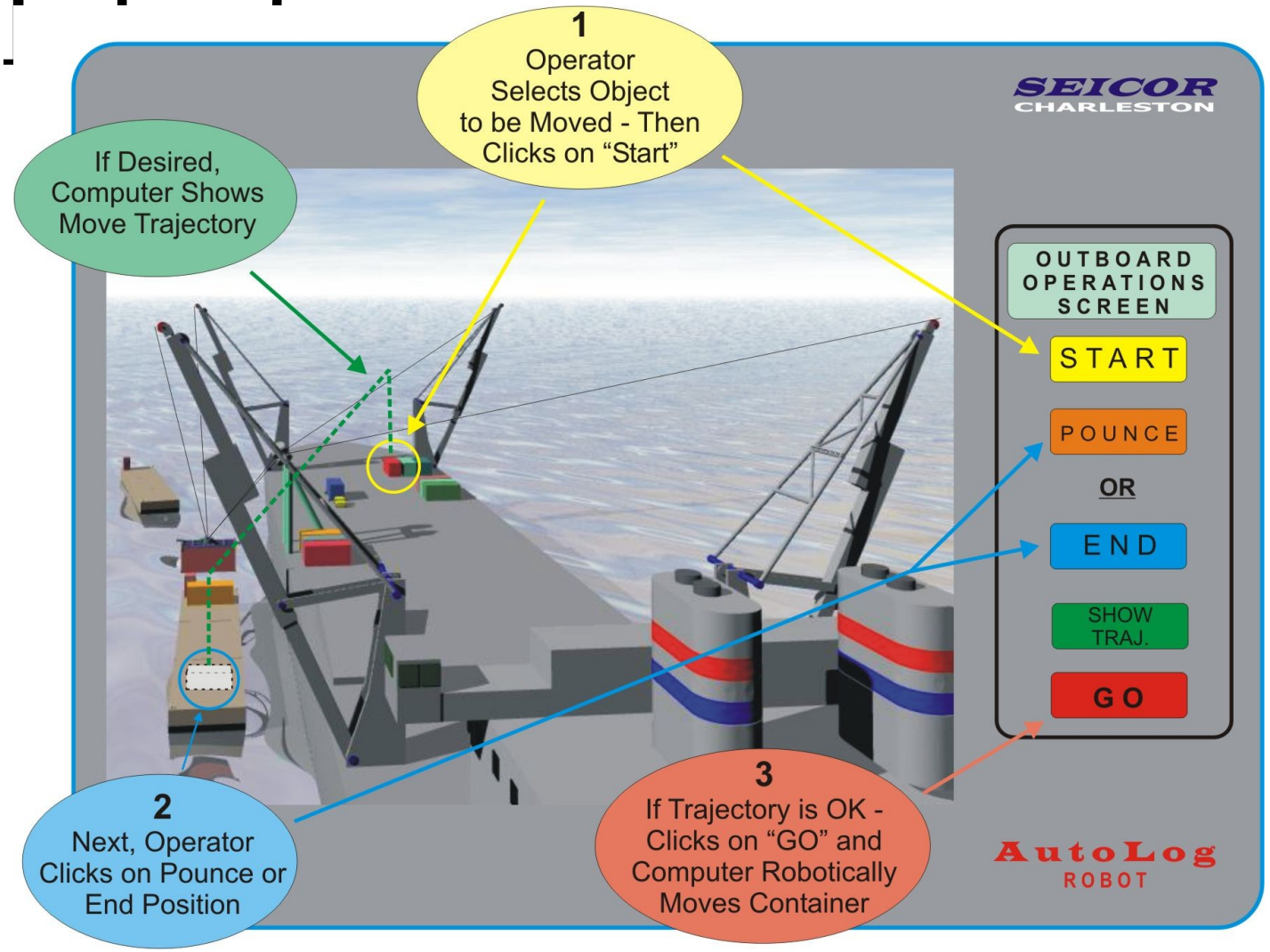

❷ CONTAINER LIFTED OUT OF CELL AND TEMPORARILY PARKED ON DECK. ACTIVE SPREADER LOWERED AND LOCKED ONTO MESSENGER SPREADER (and container)
❸ TRANSFER THEN CONTINUES AS A NORMAL DECK CARGO OPERATION
❶ ACTIVE SPREADER POSITIONED OVER CELL AND MESSENGER SPREADER LOWERED DOWN ONTO ISO
❹ 115 sec. TOTAL CYCLE
AutoLog CONTAINER TRANSFER IN-HOLD OPERATION

Model Test of Stationary Rotator Concept for Raising Containers From Hold

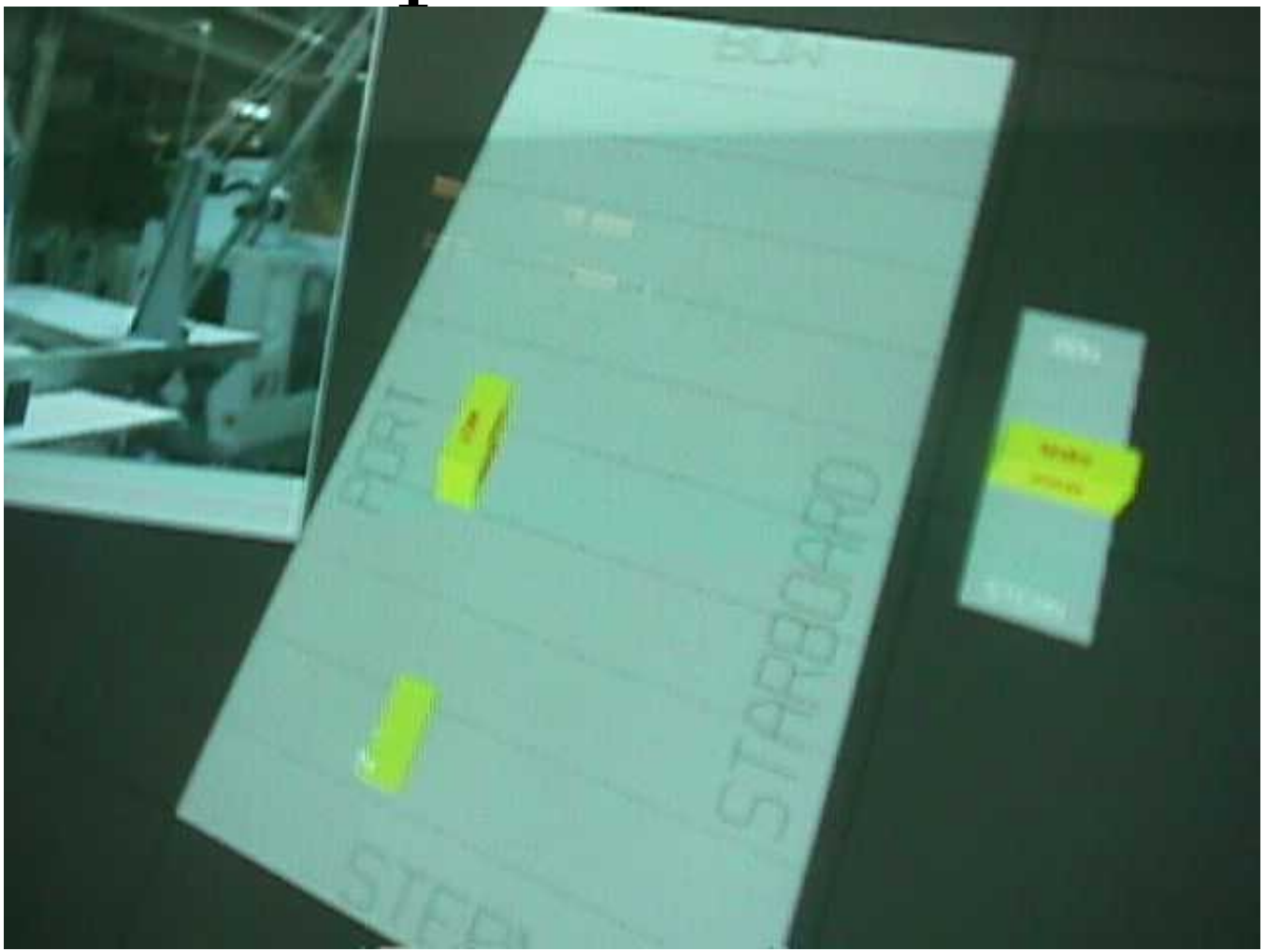
- **Pivot point stays fixed above cell.**
- **Pulley rotates in place.**
- **Main winch cable doubles back in “Fan Belt” mode.**
- **Spreader lowers down from secondary cables wound on axel.**



Point-And-Direct

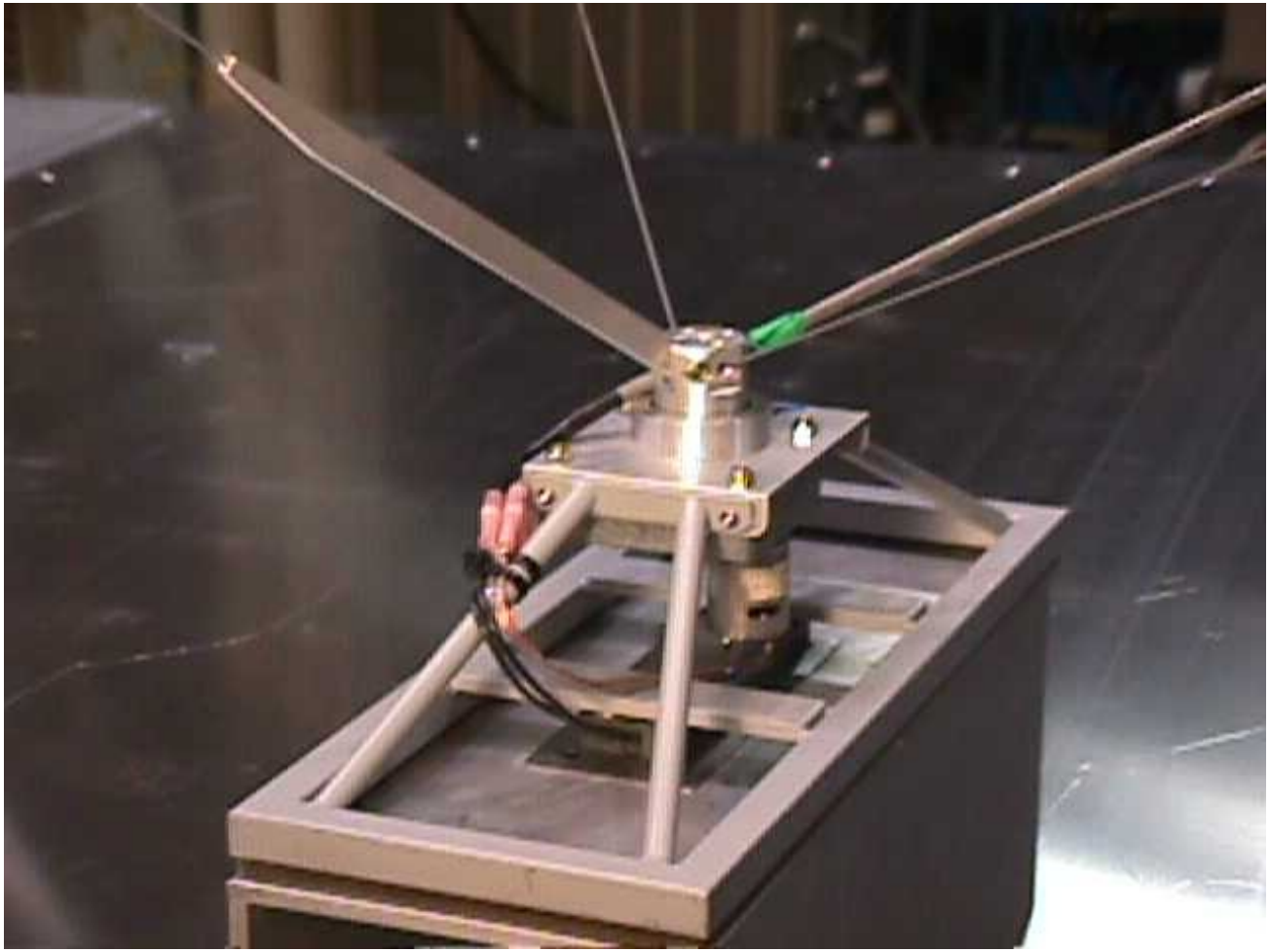


Point-And-Direct GUI with Graphical Preview

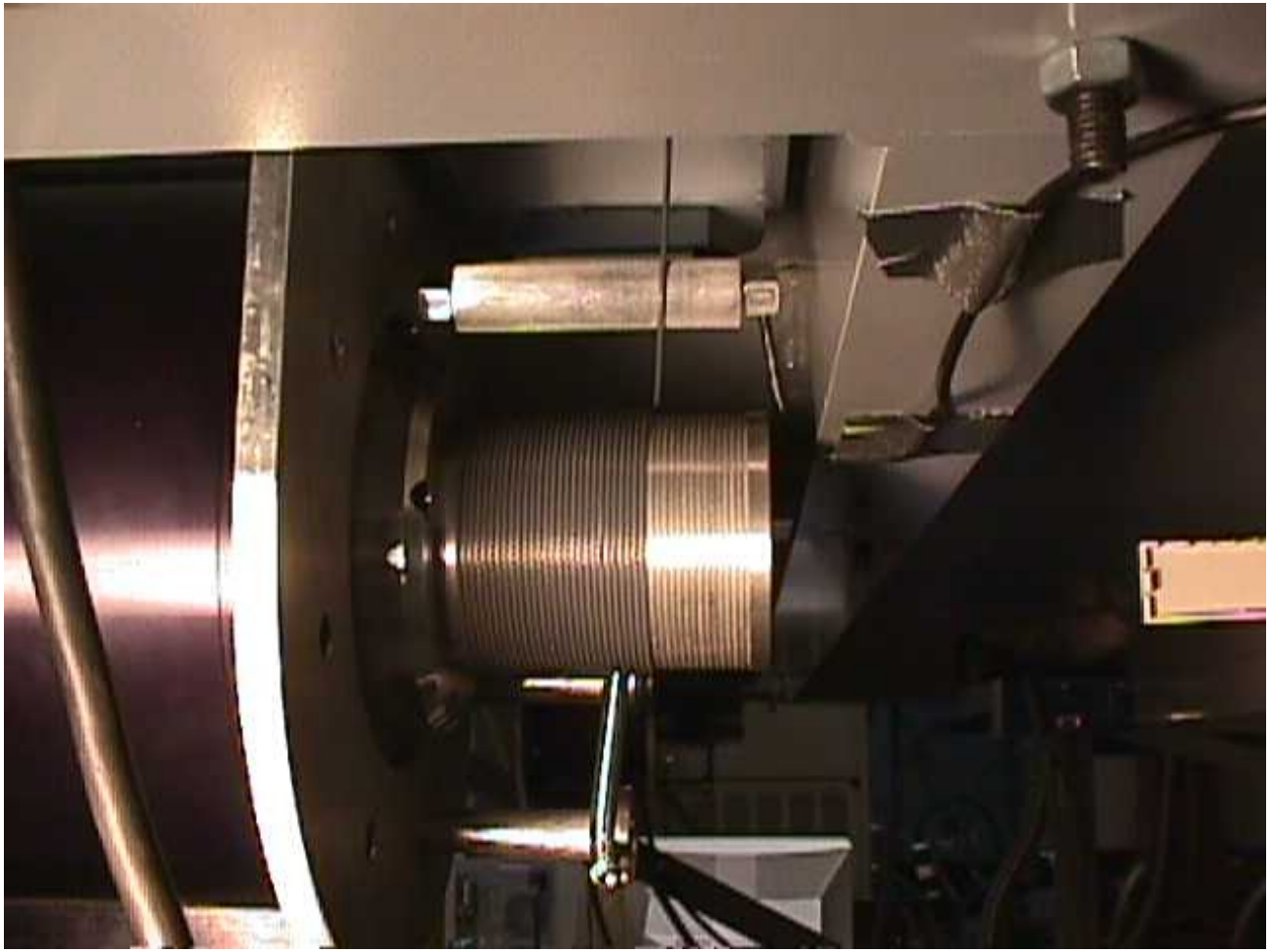


DESIGNATE

Point Positioning; Yaw Control

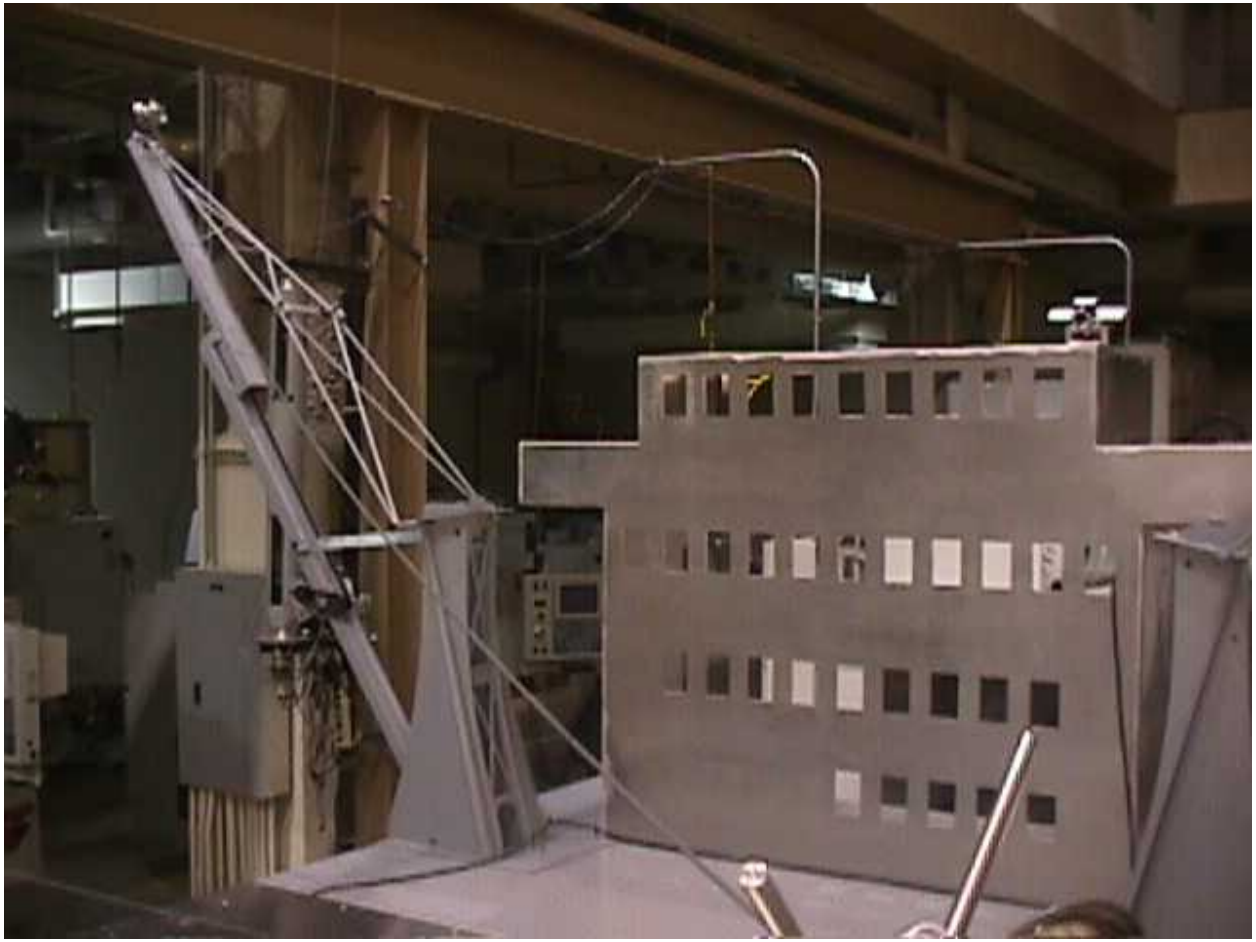


Single Layer Wrap On Drum



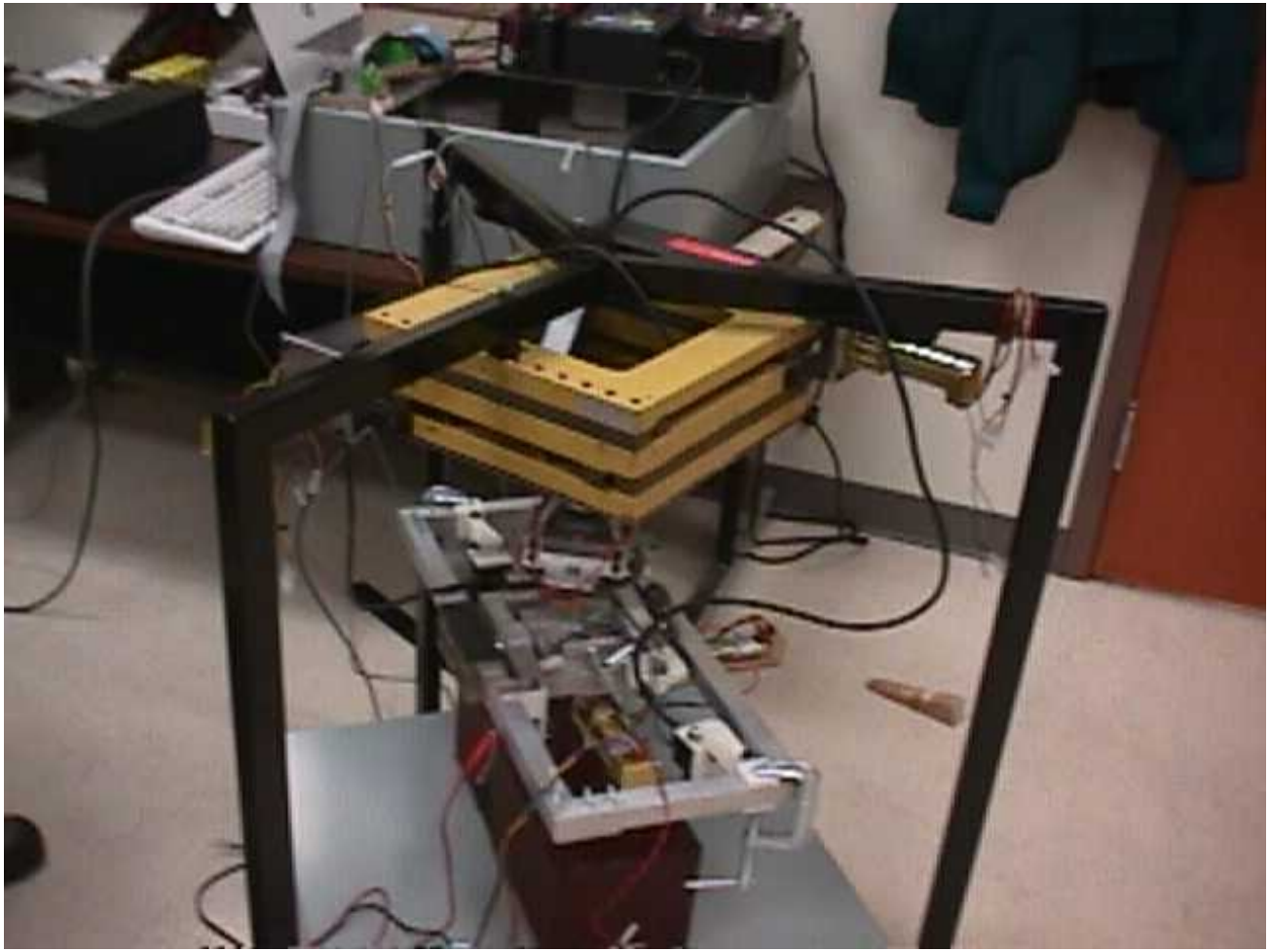
Higher Sea State Performance

Bridge Cab Eases Collaboration



Robust Machine Vision Allows For Variations

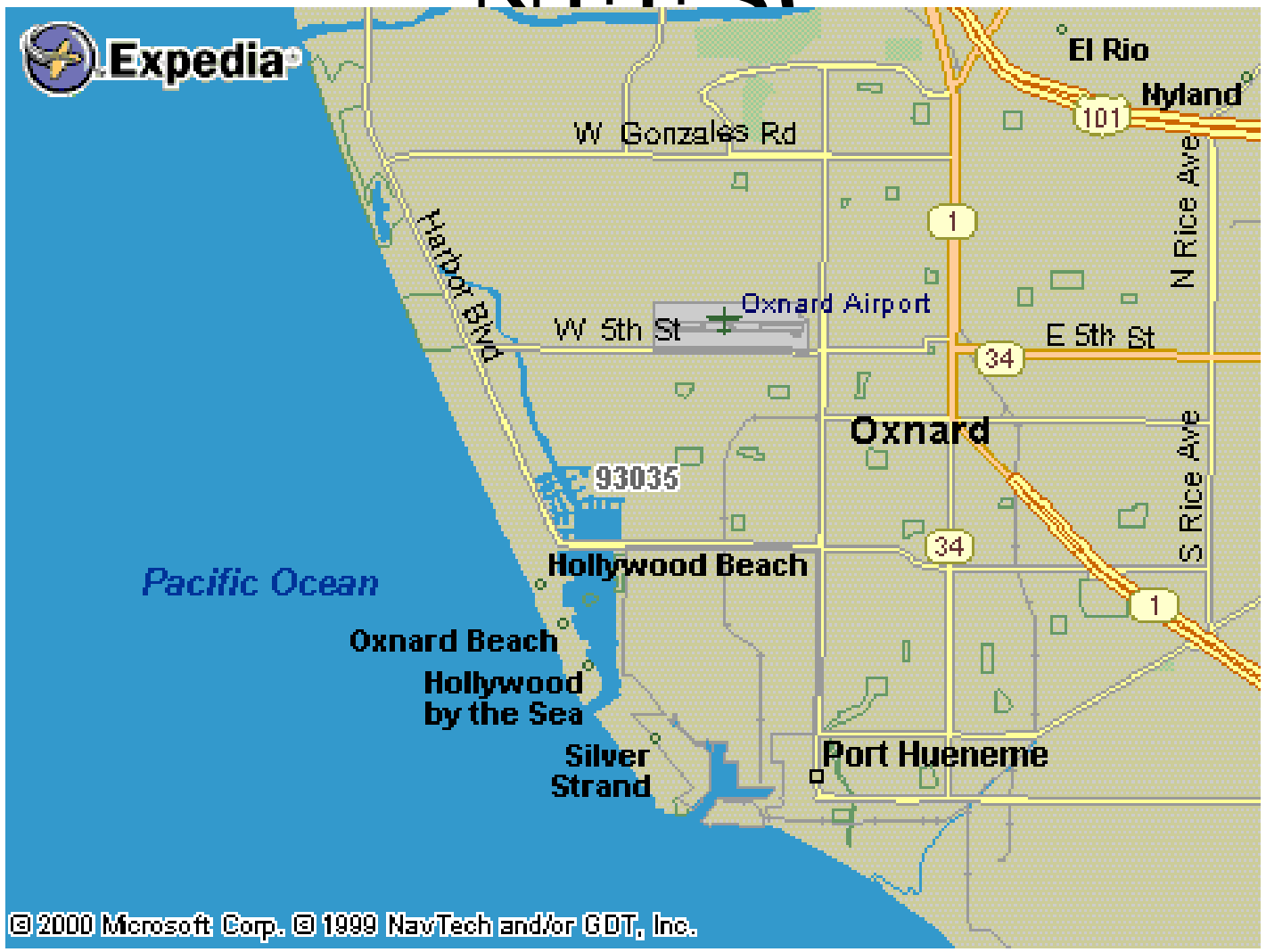
Lab Vision Platform

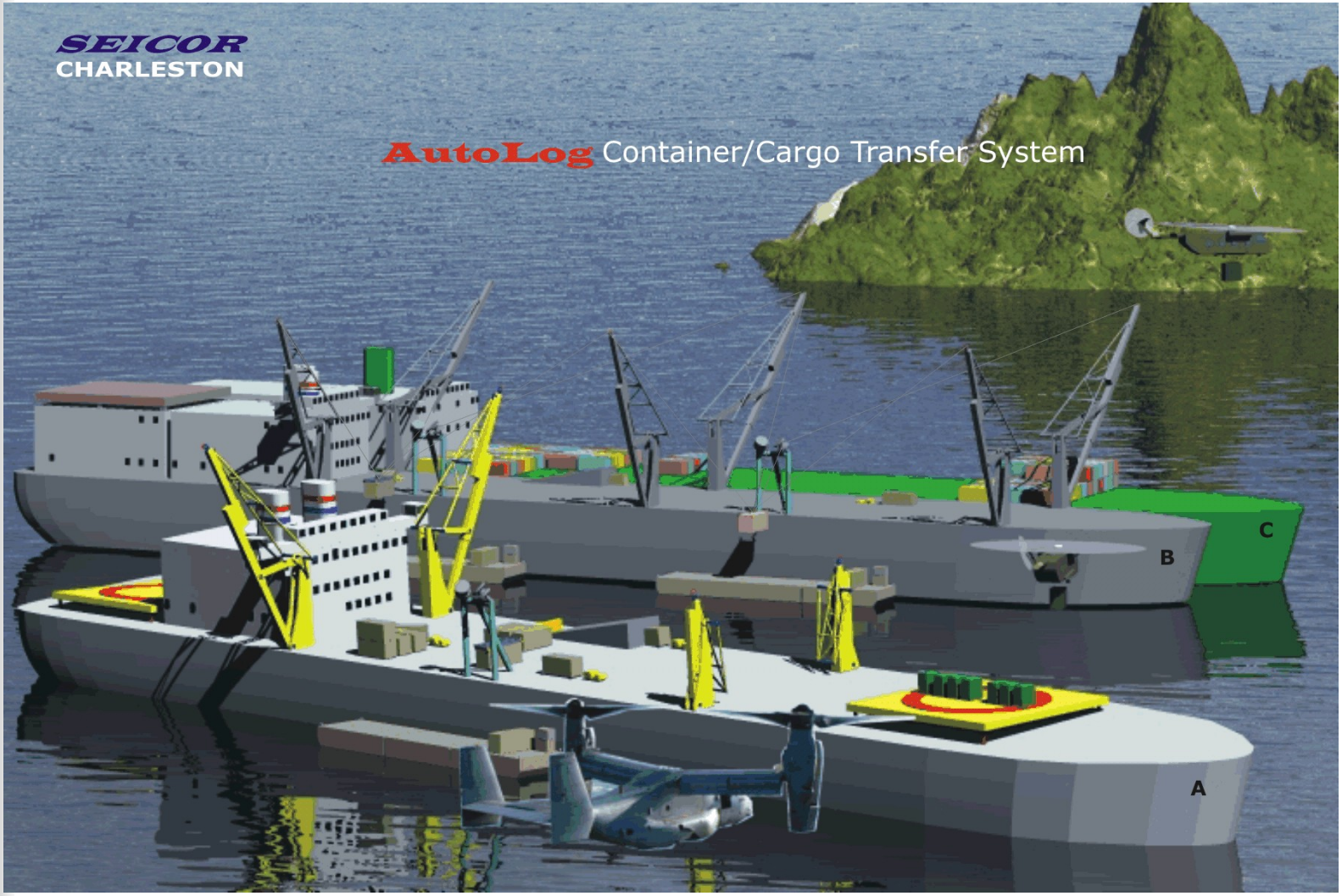


Mission Need Statement (MNS)

- **Section 5b1 says: MPF(F) must perform its offload mission in sea state 3, perform essential ship functions in sea state 5 and survive sea state 8.**

Contracted Test Site at NEESC




SEICOR
CHARLESTON
AutoLog Container/Cargo Transfer System
A
B
C